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Model SSC Dipole Magnet Cryostat Assembly at Fermilab*

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ABSTRACT

The Superconducting Super Collider (SSC) magnet development program includes the design, fabrication and testing of full length model dipole magnets. A result of the program has been the development of a magnet cryostat design. The cryostat subsystems consist of cold mass connection-slide, suspension, thermal shields, insulation, vacuum vessel and interconnections. Design details are presented along with model magnet production experience.

INTRODUCTION

The SSC Magnet Program is developing superconducting accelerator dipole magnets in successive iterations. The initial iteration[1] is complete with six full length model magnets and a thermal model having been built and tested. This initial experience along with the evolving SSC magnet system requirements have resulted in a second generation magnet cryostat design. It is this configuration that will be employed for the near term ongoing magnetic, thermal, string and accelerated life testing and will be the design considered by the SSC Magnet Industrialization Program Phase I; i.e., Technology Orientation. Five full length second iteration model magnets have been built for magnetic testing with several more units planned for the balance of the near term cold magnetic testing program.

CRYOSTAT ASSEMBLY

The Fermilab SSC model magnet cryostat assembly area is as shown by Fig. 1.

The major components of the cryostat, which supports and provides the low temperature environment for the magnet cold mass, are the cold mass connection-slide, suspension system, thermal shields, insulation, vacuum vessel and interconnections. The magnet cross section is as shown by Fig. 2.

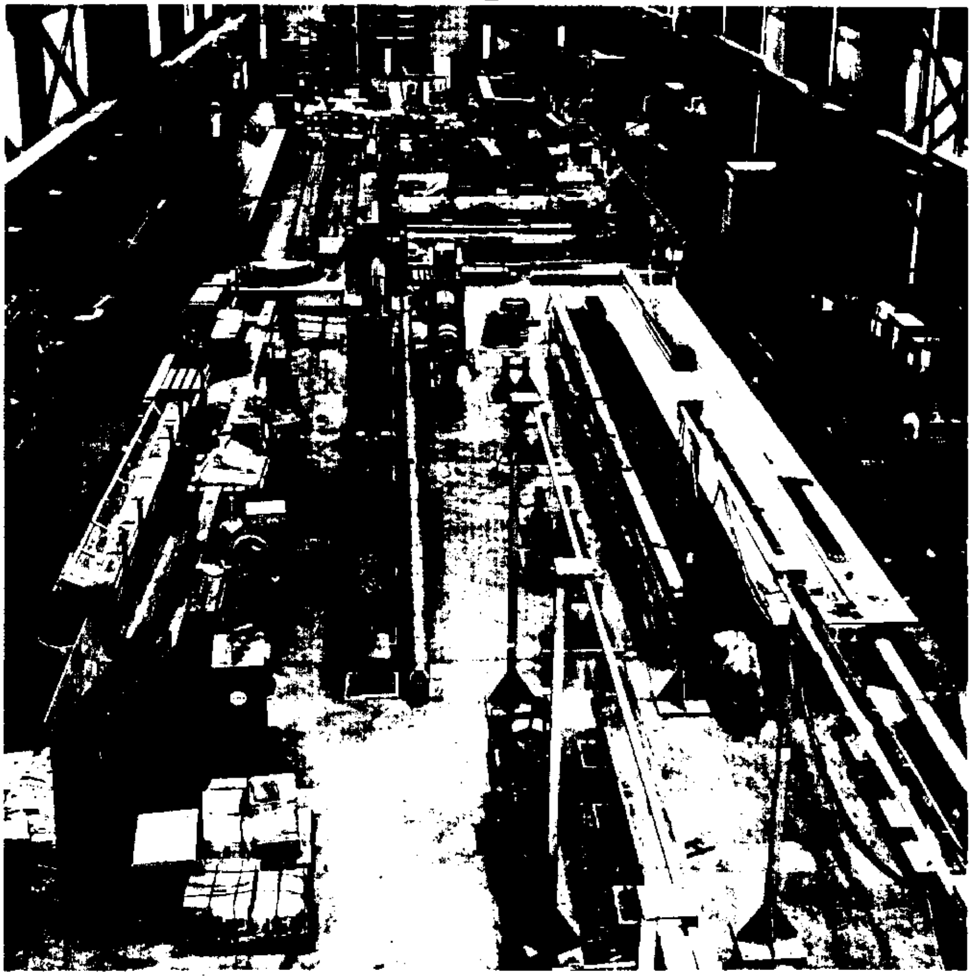

Fig. 1. Fermilab SSC Model Magnet Cryostat Assembly Area

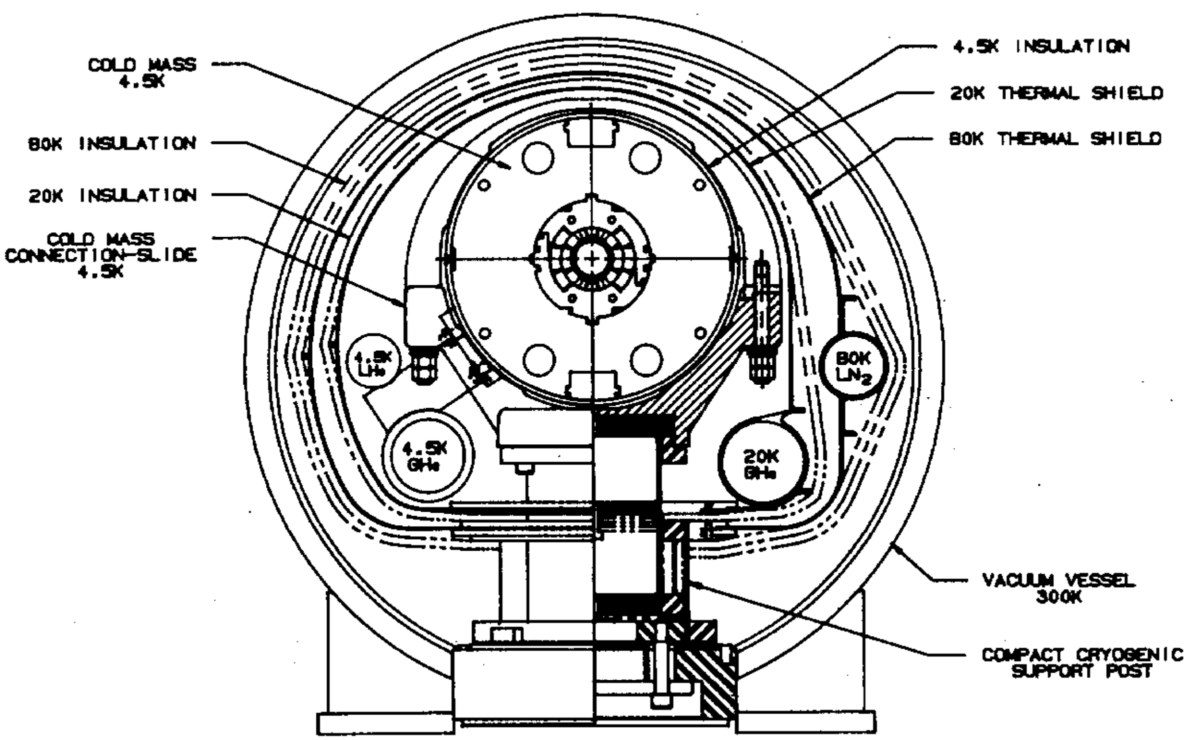

Fig. 2. Second Generation SSC Dipole Magnet Cryostat cross section

COLD MASS CONNECTION-SLIDE

The cold mass is supported by five cold mass-suspension system connections. The connections must withstand transportation and seismic loads, accommodate axial contraction of the cold mass during cooldown and warmup, accurately position the magnetic axis and fit within the compact geometry of the cryostat. Four of the connections must allow for relative axial motion, while an anchor connection fixes the cold mass axially to ground. The connections are attached to the support posts. The cold mass, connections and support posts during an initial stage of magnet assembly are as shown by Fig. 3.

The cold mass-suspension connection-slide[2] is as shown by Fig. 4. Four bearing blocks, containing removable bearing pads, contact the cold mass outer shell and establish its position. The bearing pads are supported by upper and lower cradles.

To function properly, the cold mass outer shell, or skin, must be precise in nature relative to its thickness and form and must be installed with intimate contact to the outside of the cold mass iron yoke at the bearing contact points.

The upper half of the connection retains the cold mass during transportation and seismic loading. Conical spring washers act as tensioner springs on the bolts which connect the two halves of the connection-slide. The spring action maintains uniform loading during thermal cycling and minimizes radial differential thermal contraction effects.

The connection-slides allow rotational adjustment for final alignment of the magnetic vertical plane during magnet assembly. By measuring the average vertical magnetic plane and determining its offset, the cold mass can then be rotated to compensate for this offset and fixed at the center anchor connection. The cold mass remains rotationally free at all but the center support.

Fig. 3. Cold mass connected to suspension system during early stages of assembly

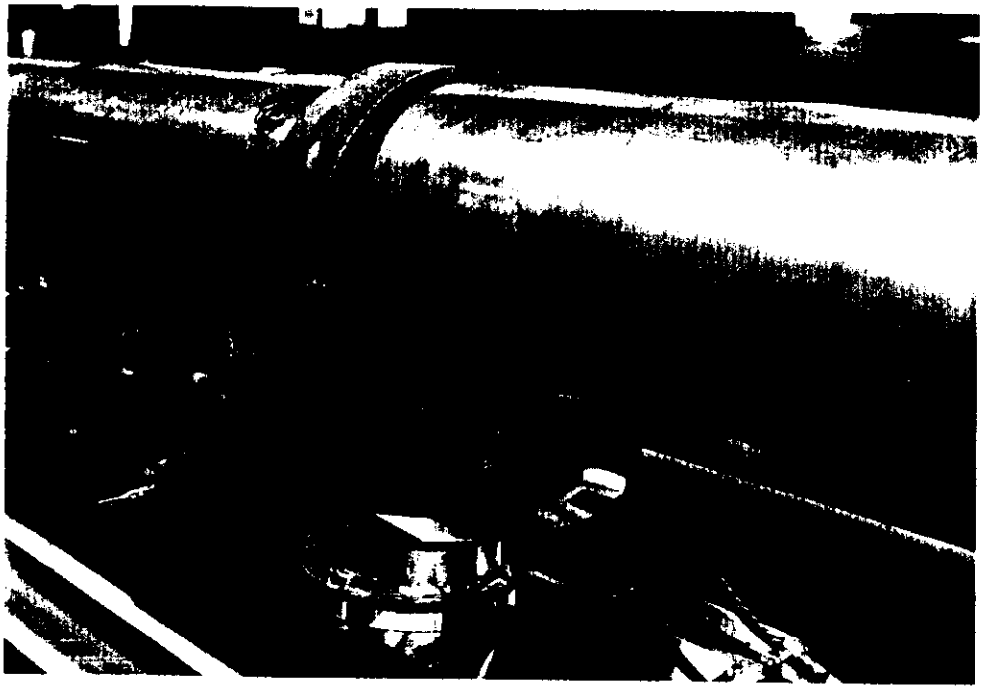

Fig. 4 Cold mass supported in cold mass connection-slide which allows axial and rotational motion

SUSPENSION SYSTEM

The cryostat suspension system performs two essential functions. It resists internally and externally generated cold mass structural loads ensuring that the position of that assembly is stable over the operating life of the magnet and it insulates the cold mass from the environment.

Support Post

A compact cryogenic support post assembly[3] is employed. The outer tube is fiberglass reinforced composite. The inner tube is graphite reinforced composite. A post heat load to 4.5 K of 0.020 W has been measured.

Anchor System

The five support posts share vertical and lateral loads. Thermal contraction of the cold mass assembly during cooldown and warmup necessitates axial sliding between the cold mass and each of the four outer posts and thus they do not contribute to axial load restraint. The center post is rigidly attached to the cold mass to ensure correct axial position within the vacuum vessel. Given no other axial restraint, the center post would carry the total axial load. A single post is incapable of handling these loads alone. Utilizing a 'strong' post at the center would impose intolerable heat loads on the cryogenic system. In order that the bending strengths of all five posts be combined to effectively act as a single axial restraint,[4] the 4.5 K end of each post is connected to that of each adjacent post with anchor tie bars. The post-tie bar anchor system is as shown by Fig. 5.

The anchor tie bar is a filament wound graphite reinforced epoxy composite tube. Graphite filaments were chosen for their thermal expansion properties. When cooled from 300 to 4.5 K, the fibers tend to grow and the epoxy tends to shrink. The net effect is a tube which changes length by only a small amount over its operating temperature range.

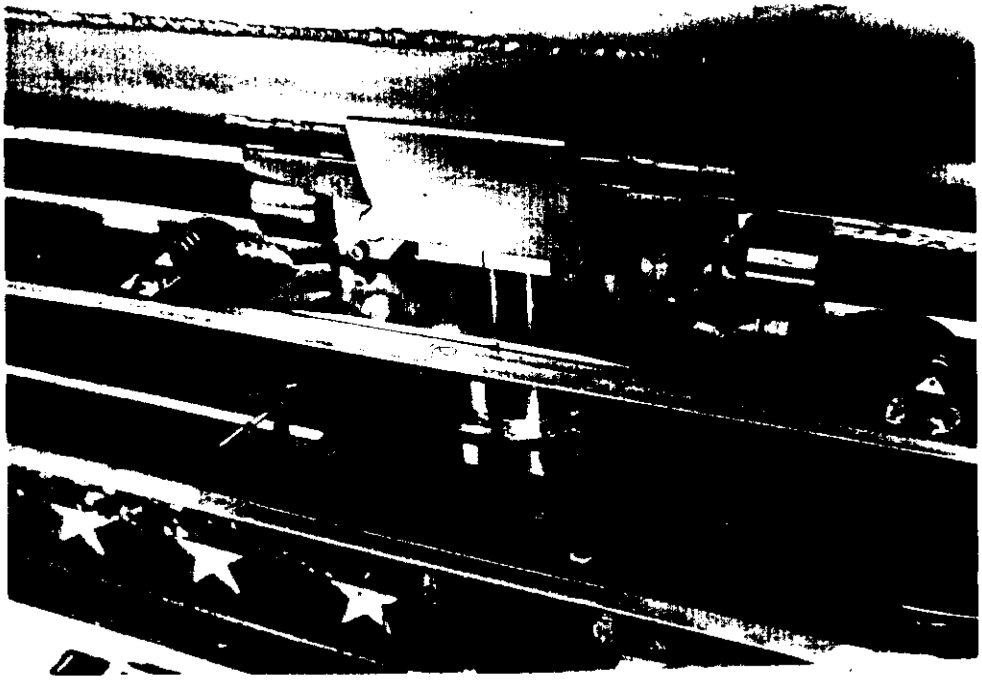

Fig. 5. Cold mass anchor connection located at magnet midspan

The importance of the tie bars is their impact on the thermal performance of the anchor system. The tie bars have both ends at 4.5 K thus contribute no conductive heat load. They lie completely inside thermal shields and thus require no penetrations through the shields.

THERMAL SHIELDS

The cryostat incorporates two thermal shields to intercept radiant heat from the environment and to provide heat sinks for the suspension system conduction heat intercepts. The shields surround the cold mass and are operated at 20 and 80K.

The shields are aluminum and are supported by the five support posts. The post-shield interface permits relative axial motion to permit the shields to move as the cryostat is cooled down and warmed up. The shields are thermally connected to the post heat conduction intercepts by copper cables. Extruded aluminum pipes carry the 20K helium gas and the liquid nitrogen used to cool the shields. Aluminum to stainless steel transition joints are required at the end of each shield cooling pipe to permit welding to the stainless steel bellows assemblies employed in the interconnections.

The uninsulated 20K shield is as shown by Fig. 6.

INSULATION

The insulation system consists of multilayer assemblies of aluminized polymer film, fabricated and installed as blankets on the cold surfaces.[5] The blanket materials are a thermal radiation reflective layer made of double aluminized polyester film and a spacer material consisting of spunbonded polyester to separate the reflective layers. Each regular blanket is an assembly of 16 layers of reflector and 15 double layers of spacer, alternately stacked.

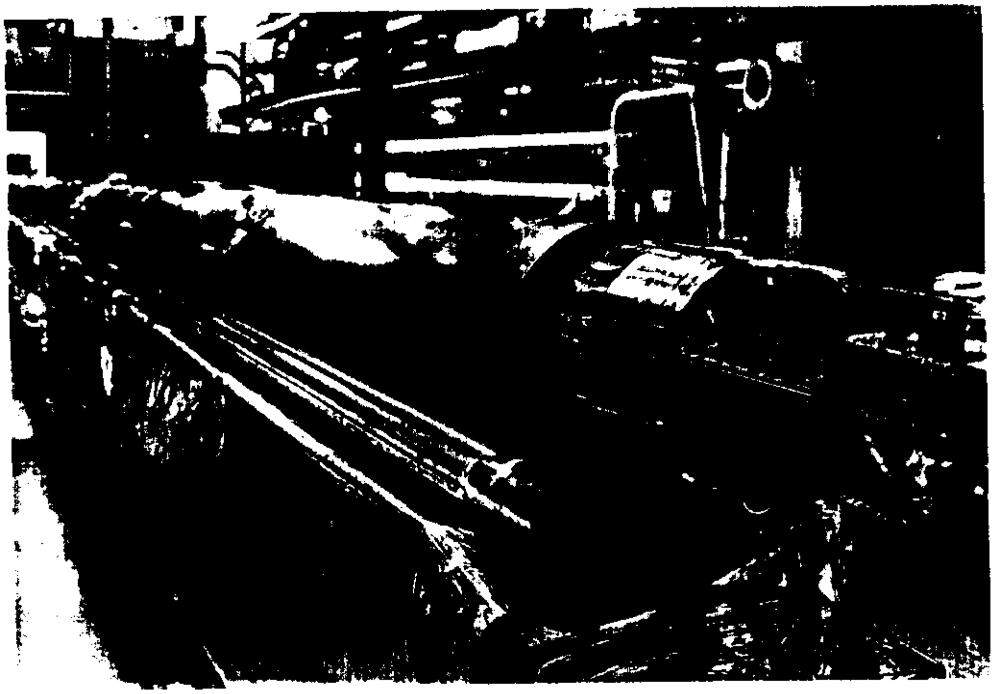

Fig. 6. Uninsulated 20K thermal shield

Insulation will be installed directly onto the cryostat cold mass to impede gas conduction heat transfer to the cold mass by residual gas and from desorbed gas released from cryostat surfaces during thermal upset conditions. The intent of the insulation is to act as a heat absorbing buffer surrounding the cold mass in order to slow the effects of transient heat loads by reducing the rate of heat transfer to the cold mass. A single blanket consisting of 5 reflecting layers and 4 spacer layers is used. The insulated cold mass is as shown by Fig. 7.

The 20K shield is insulated with two regular blankets.

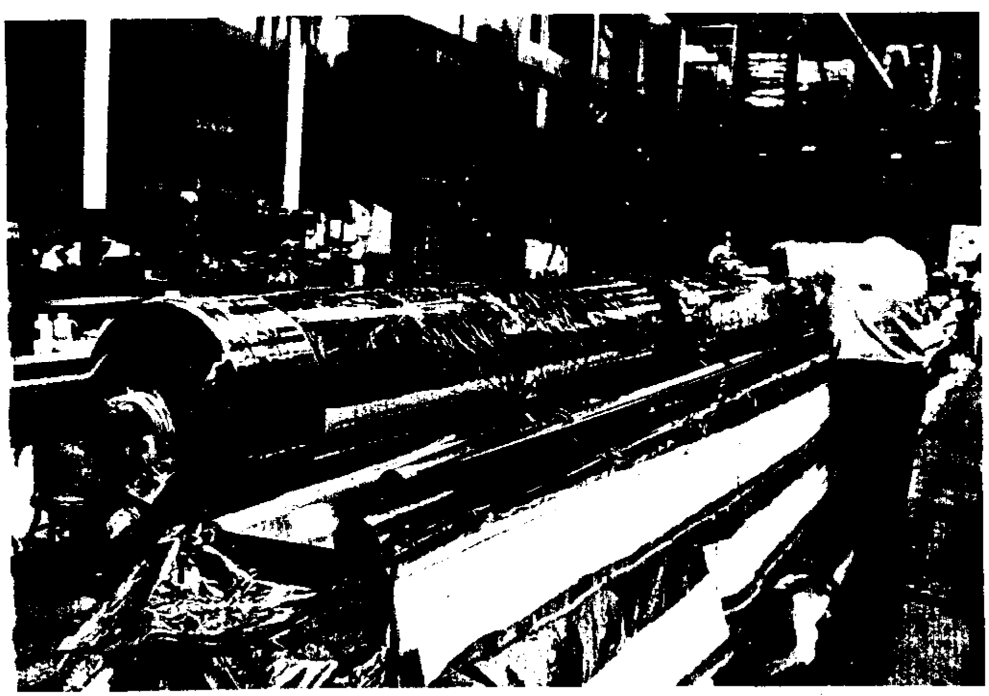

Fig. 7. Insulated cold mass

The 80K shield is insulated with four regular blankets. The insulated 80K shield is as shown by Fig. 8.

VACUUM VESSEL

The vacuum vessel provides the insulating vacuum required for the control of heat transfer to the internal components and provides for the transfer of the loads of the cryostat internal structure to ground. The vacuum vessel is circular in cross section, is equipped with bellows at its ends for interconnection and is connected to ground by means of support foot assemblies. The steel shell is 610 mm (24 in) in diameter and is 6.4 mm (0.25 in) thick.

The cold mass is supported at five points relative to the vacuum vessel. The vacuum vessel is supported at two points relative to ground by support feet. The support feet locations coincide with the intermediate position support posts.

Reinforcing rings are welded to the vacuum vessel at the mounting positions of the five internal supports. These reinforcing rings reduce bending stresses in the vacuum vessel when loads are imposed on the cold mass assembly.

The vacuum vessel is fabricated from prefabricated, full section reinforcing rings connected by short sections of tubing. The segmented assembly facilitates the vertical precurving of the vacuum vessel assembly. Precurving is employed to control; i.e., limit, the vertical sag of the cold mass magnetic axis. The vacuum vessel loaded by a calibration cold mass during inspection of the vertical precurve is as shown by Fig. 9.

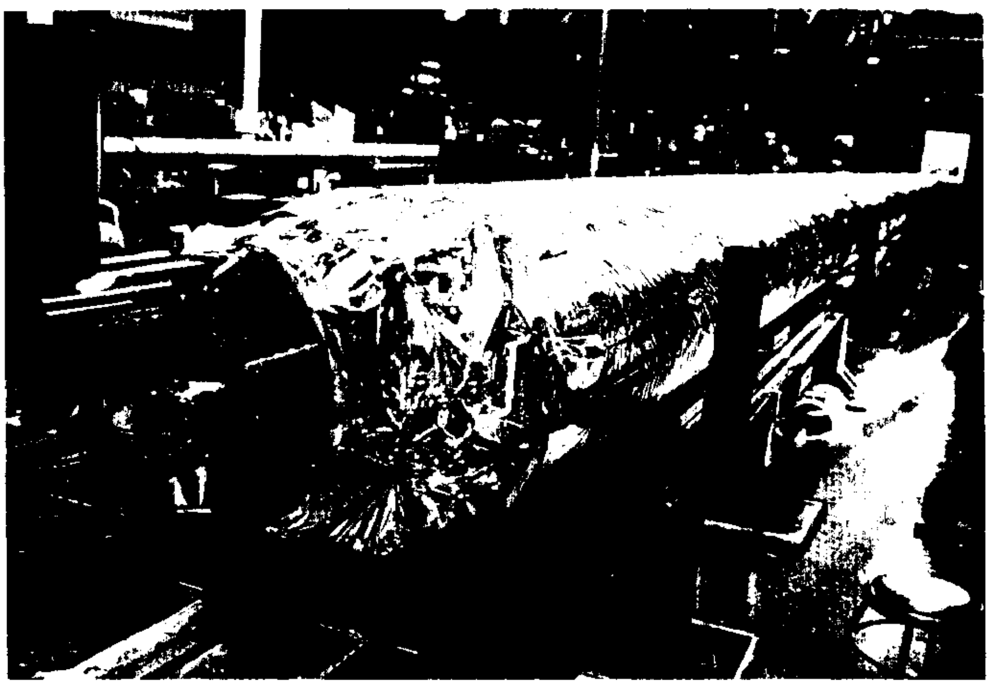

Fig. 8. Insulated 80K thermal shield

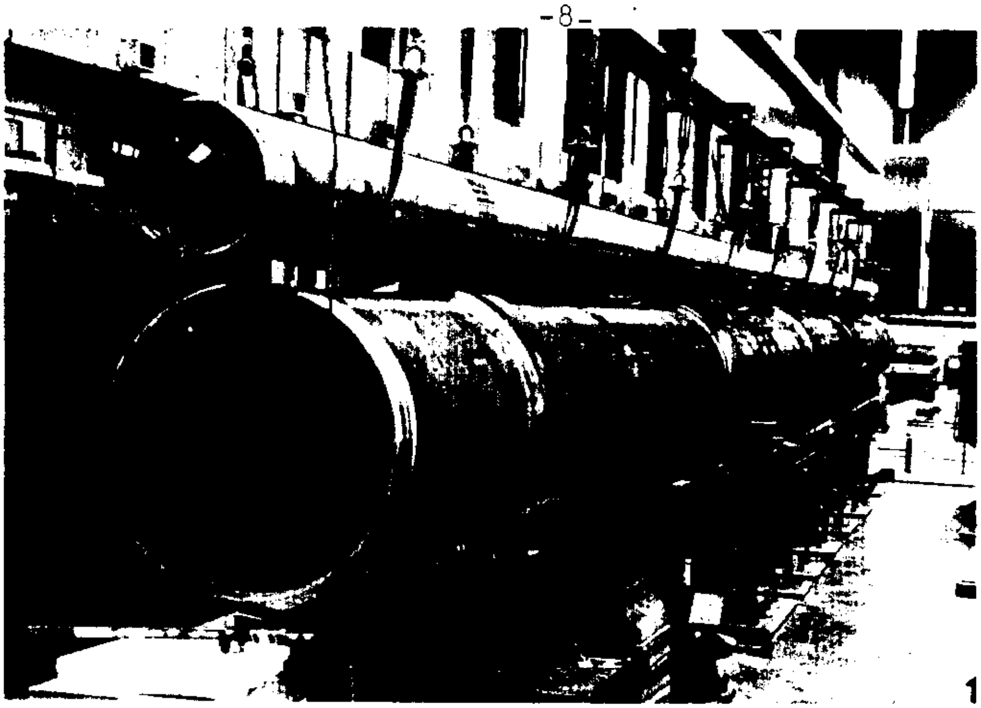

Fig. 9. The vertical precurve of the vacuum vessel is inspected after welding. A calibration cold mass is used to load the vessel at the five cold mass support points.

The completed internal cryostat assembly is inserted, by sliding, into the vacuum vessel by means of a tow tray-plate assembly installed at the bottom of the vessel shell. A completed model magnet assembly being loaded for transport to a test facility is as shown by Fig. 10.

INTERCONNECTIONS

The magnet interconnection as shown by Fig. 11, consists of seven pipes, having stainless bellows which accommodate the axial motion due to cooldown and warmup, that must be connected.[5]

All pipe ends are stainless steel except the vacuum shell connection, which is carbon steel. All connections will be welded with automatic welding units and will be cut apart with orbital pipe cutters.

The interconnection is developed radially outward from the cold mass centerline. The first connection to be made is the beam tube. The cold mass outer helium containment shell connection is then made. The next pipes to be welded are the four small pipes surrounding the cold mass. The interconnection shield bridges are made of two pieces of aluminum. They assemble with hinge arrangement on one side and rivets on the other. Small welds attach the magnet shield to the interconnection shield on one side, primarily for thermal contraction. The other side is unattached but overlaps enough for the magnet to contract upon cooldown. The shields are insulated as they are on the body of the magnet. The final connection to be made is the vacuum vessel shell.

Typical interconnection details during magnet installation are as shown by Fig. 12.

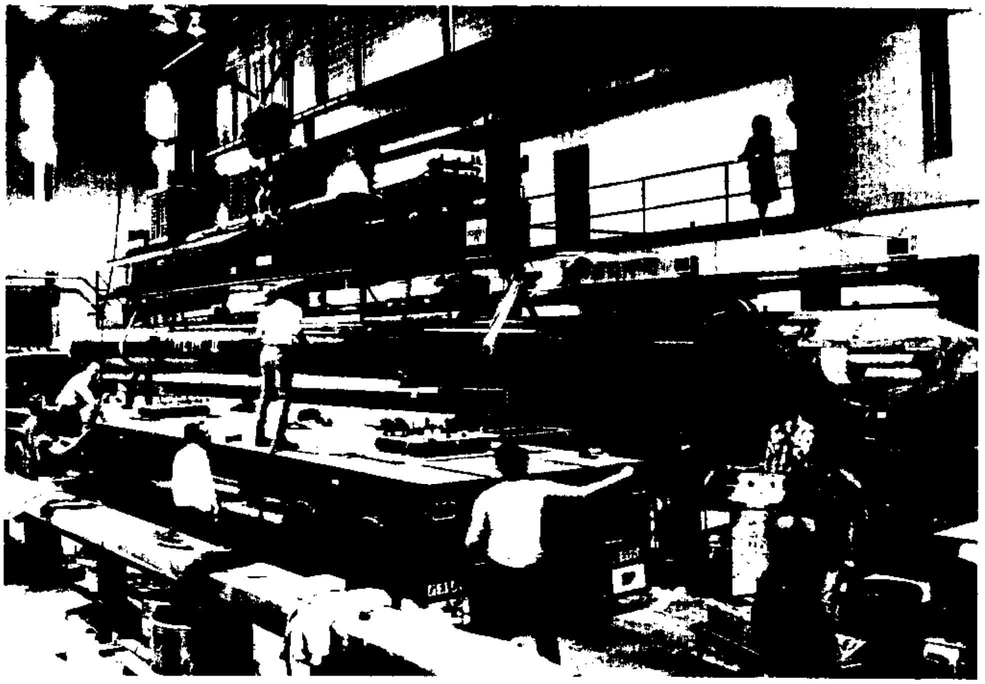

Fig. 10. SSC full length model being loaded for transport to test facility

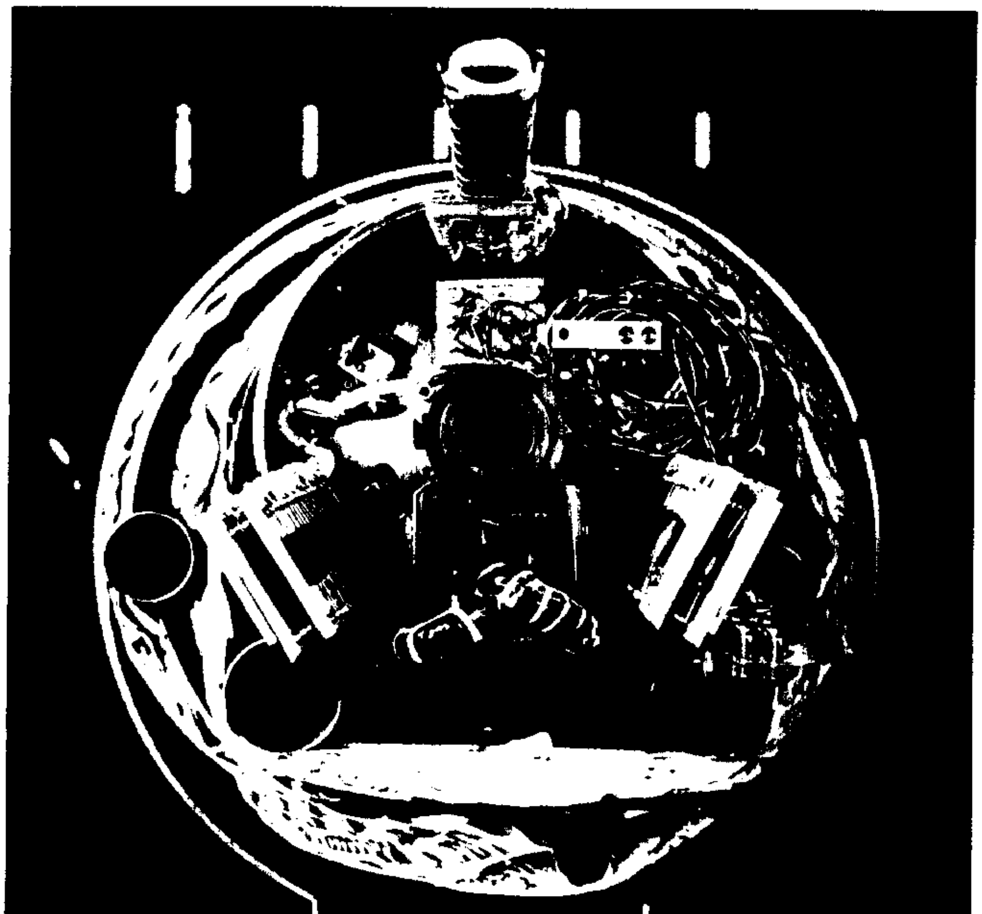

Fig. 11. End view of magnet interconnections

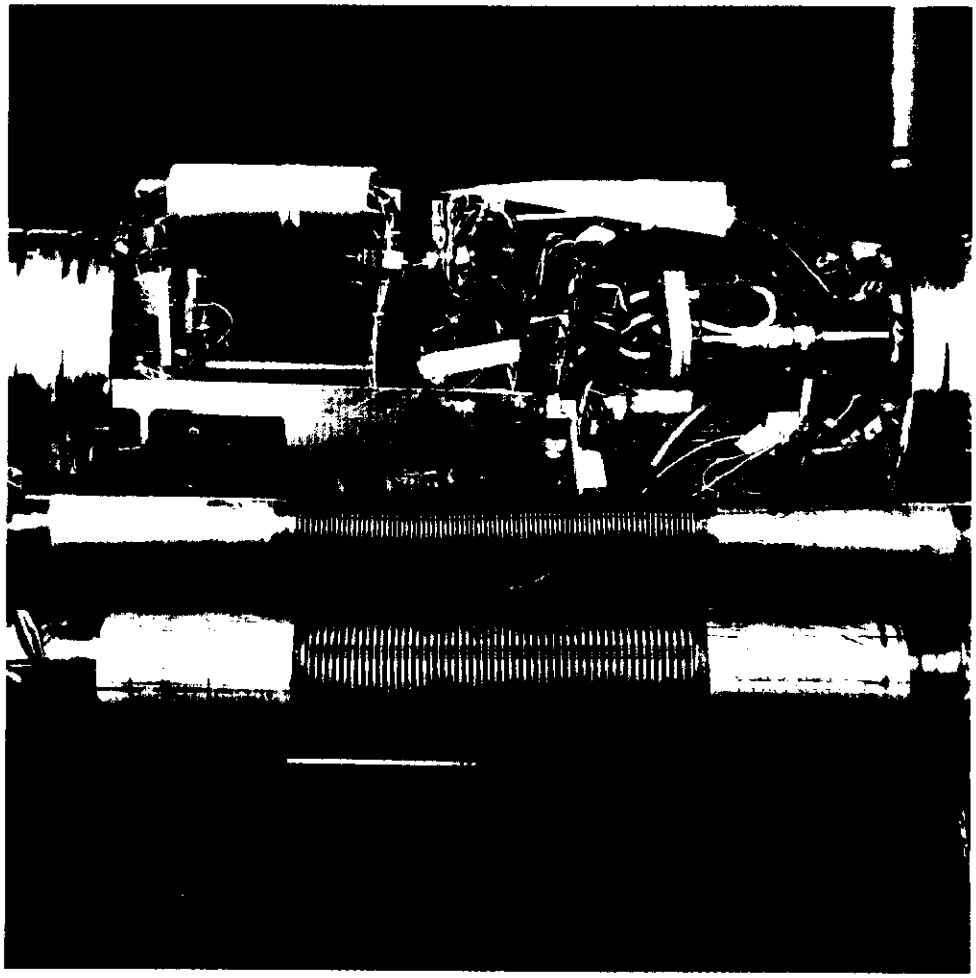

Fig. 12. Interconnection during assembly to cold magnetic test stand

MODEL MAGNET EXPERIENCE

Six units of the initial generation magnet design have been built and magnetic tested. Model magnets undergoing magnetic testing at the Fermilab Magnet Test Facility are as shown by Fig. 13.

Five model magnets utilizing the second generation cryostat design have been built and tested. This design will be employed for the balance of the near term SSC model magnet program.

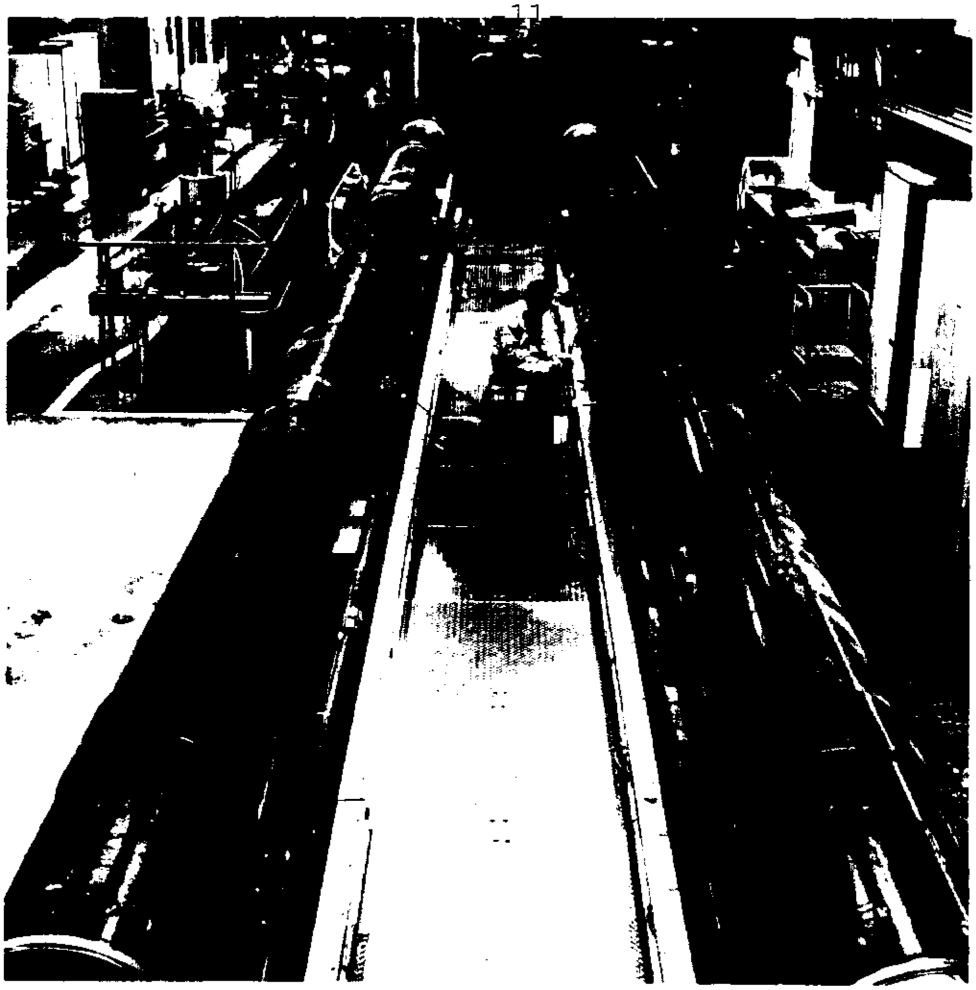

Fig. 13. SSC model magnets being prepared for magnetic testing at Fermilab

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